Surface Functionalization and Electrochemical Applications of Ultrananocrystalline Diamond

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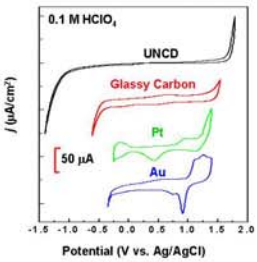
Motivation

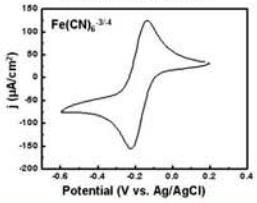
- Ultrananocrystalline diamond (UNCD) exhibits unique combination of physical, chemical, electrical and electrochemical properties well suited for a variety of applications such as tribology, cold cathodes, electrochemical electrodes, and conformal coatings on MEMS devices;
- Control and manipulation of UNCD surface chemistry are essential for tailoring surface properties for specific applications and devices of desirable features;
- Surface modification/functionalization of UNCD thin films provides the incorporation of many new properties, including catalytic activity, lubrication, optical response, molecular recognition, and biocompatibility;
- **UNCD-based hybrid bio/organic-inorganic interfaces** could enable potential applications such as optoelectronic devices, biosensors, biomedical implants, and organic/biomolecular electronics.

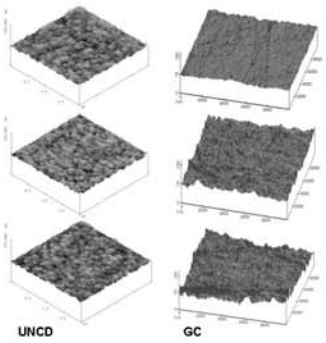
UNCD: A Robust Platform for Electrochemical Biointerfaces

N-doped UNCD possesses n-type semiconductor to semi-metallic conductivity (as high as 260 $\Omega^{-1}\cdot cm^{-1}$ (RT)).

Electrochemical Properties of UNCD







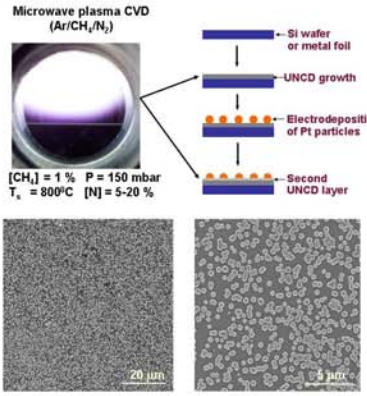
Anodic oxidation (2.5 V) in 0.1 M $HClO_4$

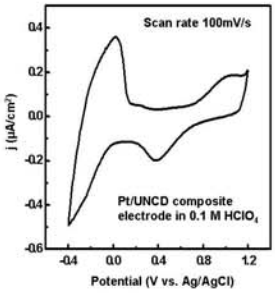
UNCD exhibits wide potential window and fast electron transfer kinetics, and superb electrochemical stability.

Surface Functionalization of UNCD

1. Integration of Hard Materials with UNCD Thin Films.

Incorporation of Pt particles onto UNCD surface — dimensionally stable electrode with controlled electrocatalytic activity.





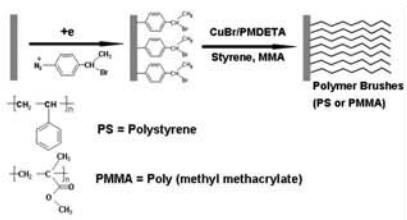
The UNCD matrix provides a thermally stable and corrosion resistant host for electrocatalyst particles.

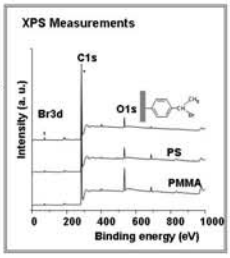
J. Wang, J. A. Carlisle, Diam. Relat. Mater., in press, 2006.

2. Integration of Soft Materials with UNCD Thin Films.

a. Covalent immobilization of polymer brushes onto UNCD surface.

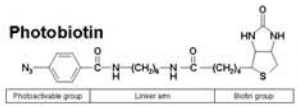
Surface Initiated Atom Transfer Radical polymerization (SI-ATRP), **in collaboration with Dr. M. M. Chehimi (University Paris, France).**



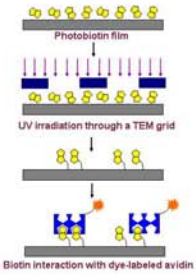


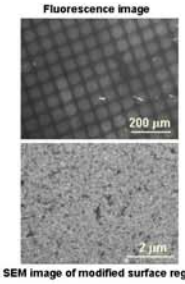
Covalent attachment of ATRP initiator to UNCD surface by electrochemical reduction of diazonium salt.

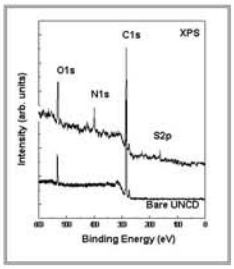
b. Protein patterning onto UNCD surfaces via photobiotin activation



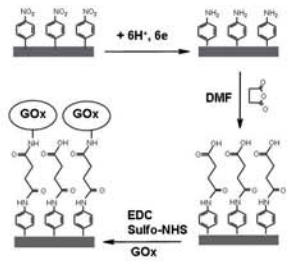
The biotinylated UNCD surface serves as an ideal platform for the attachment of biomolecules based on the biotin/avidin chemistry.

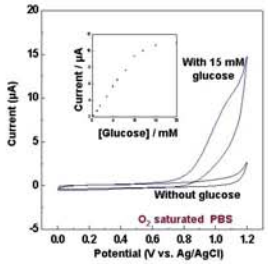






c. Biofunctionalization of UNCD surfaces — Covalent Immobilization of Redox Enzymes.





We have demonstrated the successful electrochemical detection of glucose based on glucose oxidase (GOx) functionalized UNCD electrodes.

Future Directions

1. Fabrication of Robust Metal (Metal Oxides)/UNCD Composite Electrodes

- Electroanalysis, e.g. H_2O_2 detection.
- Electrosynthesis, e.g. O_3 generation.
- Chemical waste remediation.

2. UNCD-based Organic/inorganic Interfaces

- Control the spatial structure of the organic layer.
- Investigation of the effects of surface tethered organic functionalities on the mechanical, tribological, electrical and electrochemical properties of UNCD.

3. UNCD-based Biointerfaces

- Detailed characterization of interfacial electron-transfer rate and biocatalytic activity;
- Fabrication of UNCD microelectrode array
  - Protein biochip for multianalyte analysis.
  - Nerve cell stimulation.

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